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(54) **Ti(C,N) - (Ti,Ta,W) (C,N) - Co alloy for toughness demanding cutting tool applications**

Ti(C,N) - (Ti,Ta,W) (C,N) - Co - Legierung für Zähigkeit - erfordernde Schneidwerkzeug Anwendungen

Alliage Ti(C,N) - (Ti,Ta,W) (C,N) - Co pour des applications exigeant une tenacité supérieure dans les outils de coupe

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**EP 1 052 300 B1**

## Description

[0001] The present invention relates to a sintered body of a carbonitride alloy with titanium as main component which has improved properties particularly when used as cutting tool material in cutting operations requiring high toughness. This has been achieved by combining a carbonitride based hard phase of specific chemical composition with an extremely solution hardened Co-based binder phase. Said binder phase has properties similar to the binder phase of WC-Co based materials except that it has been possible to increase the solution hardening beyond the point where eta-phase normally would appear.

[0002] Titanium-based carbonitride alloys like the ones disclosed in WO-A-98/51830, WO-A-96/22403 or EP-B2-374358, so called cermets, are produced by powder metallurgical methods and comprise carbonitride hard constituents embedded in a metallic binder phase. The hard constituent grains generally have a complex structure with a core surrounded by a rim of other composition. In addition to titanium, group VIa elements, normally both molybdenum and tungsten are added to facilitate wetting between binder and hard constituents and to strengthen the binder by means of solution hardening. Group IVa and/or Va elements, e.g. Zr, Hf, V, Nb, and Ta, are also added in all commercial alloys available today. The carbonitride forming elements are usually added as carbides, nitrides and/or carbonitrides. Historically, the binder phase in cermets has been nickel, most probably because Ti has a high solubility in Ni to facilitate sufficient wetting to obtain a low porosity level. During the 1970s a solid solution binder of cobalt and nickel was introduced. This was probably made possible by improved raw material quality, in particular a lower impurity level of oxygen. Today all commercial alloys contain 3-25 wt% of a solid solution binder with relative proportions Co/(Co+Ni) in the range 50-75 at%.

[0003] Cermets are today well established as insert material in the metal cutting industry. Compared to WC-Co based materials they have excellent chemical stability in contact with hot steel also in uncoated state, but substantially lower strength. This makes them most suited for finishing operations, which generally are characterized by limited mechanical loads on the cutting edge and a high surface finish requirement on the finished component. Unfortunately, cermets suffer from an unpredictable wear behavior. In a worst case, end of tool life is caused by bulk fracture which may lead to severe damage of work piece as well as tool holder and machine. More often end of tool life is determined by small edge line fractures, which abruptly change the surface finish or dimensions obtained. Common for both types of damages is that they are sudden in nature and occur without previous warning. For these reasons cermets have a relatively low market share especially in modern, highly automated production which relies on a high degree of predictability to avoid costly production stops.

[0004] The obvious way to improve predictability would be to increase the toughness of the material and work with a larger safety margin. However, so far this has not been possible without simultaneously reducing the wear- and deformation resistance of the material to a degree, which substantially lowers productivity.

[0005] It is an object of the present invention to solve precisely the problem described above. It is indeed possible to design and produce a material with substantially improved toughness while maintaining deformation and wear resistance on the same level as conventional cermets. This has been achieved by working with the alloy system Ti-Ta-W-C-N-Co and by the combination of features as disclosed in claim 1. Within this system a set of constraints has been found rendering optimum properties for the intended application area. As so often, the solution is not one single major change but rather a lucky combination of the following precise requirements which together give the desired properties:

1. The conventional Ni containing binder phase is replaced with a Co-based binder as in WC-Co alloys, i.e. the chemically stable hard phase of cermets is combined with the tough binder of cemented carbides. Co and Ni behave substantially differently during deformation and solve substantially different amounts of the individual carbonitride formers. For these reasons Co and Ni are not interchangeable as has previously commonly been believed. For applications such as semifinish turning of steel, including interrupted cuts and profiling, or finish milling the amount of Co required is 12-14.5 at%.

2. The binder must be sufficiently solution hardened. This is accomplished by designing the hard phase in such a way that substantial amounts of predominantly W atoms are dissolved in the Co. It is well known that Ti, Ta, C and N all have low or very low solubility in Co while W has high solubility. Thus, within this alloy system the binder will be essentially a Co-W solid solution as is the case for WC-Co alloys. Solution hardening is usually measured indirectly as relative magnetic saturation, i.e. the ratio of the magnetic saturation of the binder phase in the alloy compared to the magnetic saturation of an equal amount of pure cobalt. For WC-Co alloys close to the graphite limit a relative magnetic saturation of "one" is obtained. By decreasing the carbon content of the alloy solution hardening is increased and reaches a maximum at a relative magnetic saturation of about 0.75. Below this value eta-phase is formed and solution hardening can no longer be increased. For the alloys in the present invention it has been found that solution hardening can be driven substantially further compared to WC-Co alloys by a combination of relatively high N content, high Ta content and low interstitial balance. The exact reason for this is un-

known but leads to improved properties probably since thermal expansion of the cermet hard phase is larger than for WC and thus higher solution hardening is required to avoid fatigue by plastic deformation of the binder phase during thermo-mechanical cycling. The relative magnetic saturation should be kept below 0.65.

3. To combine high toughness and deformation resistance with good edge line quality a material with a high binder phase content combined with a small hard phase grain size is generally required. The conventional way to decrease the grain size in cermets has been to decrease the raw material grain size and increase the N content to prevent grain growth. However, for the alloys of the present invention a high N content alone has not proved sufficient to obtain the desired properties. The solution has instead turned out to be a combination of a relatively high N content ( $N/(C+N)$  in the range 35-40 at%) and a Ta content in the range 4-7 at% and preferably 4-5 at%. For alloys with Co-based binder, the grain size is best determined by measuring the coercive force, Hc. For the alloys of the present invention the coercive force should be above 13 kA/m.

4. Within reasonable limits, the amount of W added to the material does not directly influence the properties. However, the W content should be in the range 3-8 at% to avoid an unacceptably high porosity level.

5. The material described above is extremely reactive during sintering. Uncontrolled sintering parameters, e.g. conventional vacuum sintering, may lead to several undesirable effects. Examples of such effects are large compositional gradients towards the surface due to interaction with the sintering atmosphere and high porosity due to gas formation within the alloy after pore closure. Thus, production of the material has also required development of a unique sintering process described in EP-A-1 052 297 filed concurrently herewith. Using this process a material is obtained which, within reasonable measurement limits and statistical fluctuations, has the same chemical composition from the center to the surface.

#### Example 1

[0006] Powders of Ti(C,N), WC, TaC and Co were mixed to obtain the proportions (at%) 35.9 Ti, 3.6 W, 4.3 Ta, 12.4 Co and a  $N/(C+N)$  ratio of 38 at%. The powder was wet milled, spray dried and pressed into TNMG160408-pf inserts.

[0007] Inserts in the same style were produced from an other powder, which is a well established grade within its application area (P 15). This grade (=reference) had the following composition (at%): 34.2 Ti, 4.1 W, 2.5 Ta, 2.0 Mo, 0.8 Nb, 8.2 Co, 4.2 Ni and a  $N/(C+N)$  ratio of 37 at%.

[0008] Inserts from the reference powder were sintered using a standard process while the inserts according to the invention were sintered according to the sintering process disclosed in SE 9901581-0. Figure 1 shows a scanning electron microscopy image of the microstructure obtained for the inserts produced according to the invention.

[0009] Measurements of physical properties are shown in the table below:

	Hc, kA/m	rel. magnetic saturation	density, g/cm <sup>3</sup>	porosity, ISO 4505
Reference	n.a.	n.a.	7.26	A02 (A08 center)
Invention	14.9	0.56	7.25	A02-A04

[0010] Note that coercive force and relative magnetic saturation are not relevant measurement techniques for Ni-containing alloys since in that case coercive force does not have a clear coupling to grain size and relative magnetic saturation is predominantly a measurement of all the other elements solved in the binder apart from tungsten. Inserts from both powders were coated with a standard Ti(C,N)-PVD layer.

#### Example 2

[0011] Cutting tests in a highly toughness demanding work piece were done with following cutting data:

Work piece material: SCR420H V=200 m/min, f=0.2 mm/r, d.o.c=0.5 mm, coolant

Result: (No of passes before breakage, average of four edges)

Reference: 46

Invention: 97

#### Example 3

[0012] Wear resistance tests of the same materials were done with following cutting data.

Work piece material: Ovako 825B

V=250 m/min, f=0,15 mm/r, d.o.c=1 mm

[0013] The table below shows the Vb-value as a function of time, tool life criterion was Vb  $\geq$  0,25 mm (average of two edges)

	4	8	12	16	20	24	28	32	36	min
Reference	0,04	0,07	0,09	0,10	0,14	0,17	0,25	-	-	
Invention	0,04	0,05	0,07	0,07	0,09	0,15	0,19	0,23	0,25	

[0014] From the examples above it is clear that compared to a prior art material, inserts produced according to the invention has substantially improved toughness while maintaining comparable wear resistance.

## Claims

1. A sintered titanium based carbonitride alloy body consisting of Ti, Ta, W, C, N and Co, suitable for toughness demanding finishing operations wherein the alloy contains 4-7 at% Ta, 3-8 at% W with a N/(C+N) ratio in the range 35-40 the contents of N and (C+N) expressed in their atomic fractions, the binder is formed of 12-14.5 at% Co with only impurity levels of Ni and Fe, said Co is solution hardened mainly by W atoms to obtain a relative magnetic saturation below 0.65 and said alloy body, within typical measurement limits and typical statistical fluctuations, has the same chemical composition from the center to the surface.
2. A titanium-based carbonitride alloy according to the previous claim **characterized in that** the alloy contains 4-5 at% Ta.
3. A titanium-based carbonitride alloy according to any of the previous claims **characterized in that** measurement of the coercive force renders a value above 13 kA/m.

## Patentansprüche

1. Gesinterter Carbonitridlegierungskörper auf Titanbasis, bestehend aus Ti, Ta, W, C, N und Co, der für Nachbearbeitungen geeignet ist, die hohe Verformungsbeständigkeit in Kombination mit relativ hoher Zähigkeit erfordern, wobei die Legierung 4 bis 7 Atom-% Ta und 3 bis 8 Atom-% W mit einem Verhältnis N/(C + N) im Bereich von 35 bis 40 enthält, worin die Gehalte an N und (C + N) in ihren Atomanteilen ausgedrückt sind, das Bindemittel von 9 bis 10,5 Atom-% Co mit nur Verunreinigungsmengen an Ni und Fe gebildet ist, das Co hauptsächlich durch W-Atome lösungsgehärtet ist, um eine relative magnetische Sättigung unter 0,65 zu erhalten, und der Legierungskörper in typischen Meßgrenzen und typischen statistischen Fluktuationen die gleiche chemische Zusammensetzung von der Mitte bis zur Oberfläche hin hat.
2. Carbonitridlegierung auf Titanbasis nach dem vorausgehenden Anspruch, **dadurch gekennzeichnet, dass** die Legierung 4 bis 5 Atom-% Ta enthält.
3. Carbonitridlegierung auf Titanbasis nach einem der vorausgehenden Ansprüche, **dadurch gekennzeichnet, dass** die Messung der Coerzitivkraft einen Wert oberhalb 14 bis 17 kA/m ergibt.

## Revendications

1. Corps fritté d'un alliage de carbonitride à base de titane contenant du Ti, Ta, W, C, N et Co, approprié pour des opérations de finition nécessitant une résistance à la déformation élevée ainsi qu'une ténacité relativement élevée dans lequel l'alliage contient de 4 à 7 %at de Ta, de 3 à 8 %at de W et un rapport N/(C+N) dans l'intervalle de 35 à 40, les teneurs en N et en (C+N) étant exprimées en fraction atomique, le liant est formé de 9 à 10,5 %at de Co avec uniquement des niveaux d'impuretés de Ni et de Fe, ledit Co est durci en solution principalement par les atomes W pour obtenir une saturation magnétique relative inférieure à 0,65 et ledit corps de l'alliage, dans des limites de mesures typiques et des fluctuations statistiques typiques, présente la même composition chimique à

## EP 1 052 300 B1

partir du centre jusqu'à la surface.

2. Alliage de carbonitrure à base de titane selon la revendication précédente **caractérisé en ce que** l'alliage contient de 4 à 5 %at de Ta.
3. Alliage de carbonitrure à base de titane selon les revendications précédentes **caractérisé en ce que** la mesure de la force coercitive présente une valeur de 14 à 17 kA/m.

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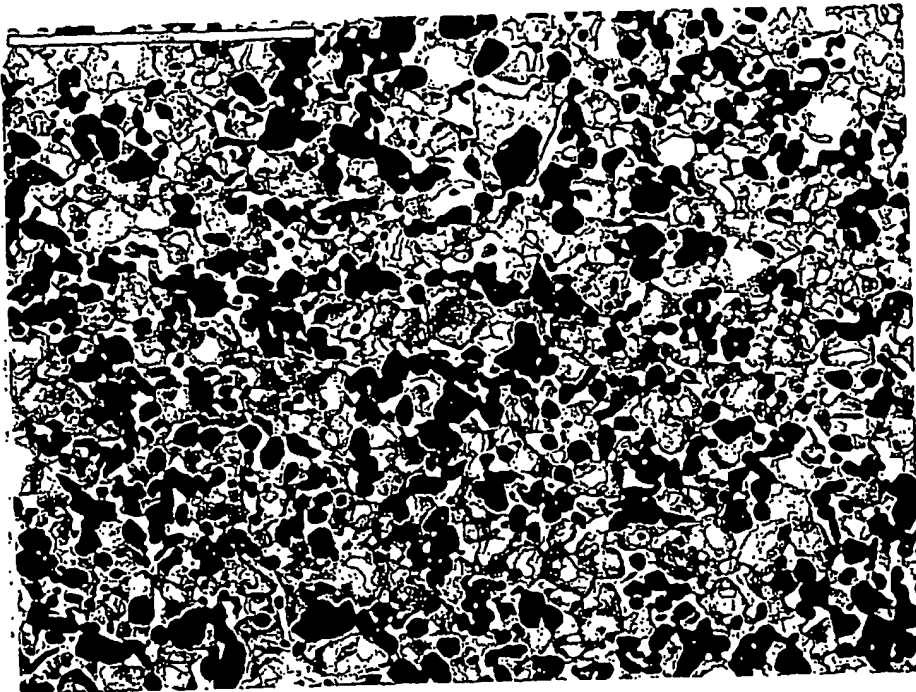
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4000x

**Fig. 1**